Bulk Properties of Grain as Affected by Self-Propelled Rotational Type Grain Spreaders

C. S. Chang, H. H. Converse, C. R. Martin
MEMBER ASAE MEMBER ASAE MEMBER ASAE

ABSTRACT

A self-propelled rotational 4-trough grain spreader constructed at the U.S. Grain Marketing Research Laboratory and two commercially available rotational type grain spreaders were used to fill a 6.4-m diameter bin with wheat, corn, and grain sorghum. The grain for filling was choke-fed through an orifice to the spreaders. Under this operating condition, the uniformity of fine material distribution in the grain mass was generally the same for bins filled with or without a spreader. Damage to the grain during bin filling was lower when it was choke-fed through an orifice to the bin than when it was transferred through a conventional spout. When the 4-trough spreader was used, the surface of the grain in the bin was reasonably level, but the dustiness of air in the bin was greater than when a spreader was not used. The bulk density and airflow resistance of grain transferred into a bin by spreaders were higher than those for grain transferred without a spreader. At the same airflow rate, the power required to move air through the grain transferred into a bin by spreaders was higher than that for grain transferred without a spreader.

INTRODUCTION

A self-propelled rotational type 4-trough grain spreader constructed at the U.S. Grain Marketing Research Laboratory was tested previously (Chang et al., 1981). Results showed that use of the grain spreader to fill a bin with corn significantly improved the uniformity of fine material distribution in the grain mass and provided a reasonably level surface without hand labor. When no spreader (spout only) was used the fine material concentrated in the bin center within a radius of about 60 cm. Fine material content in this region was 4 to 5 times higher than the average. These results were obtained from tests conducted at a relatively high grain velocity. Test grain was elevated by a grain elevator to a height of 40 m above the top of the test bin, then discharged into a spouting system that directed the flow of grain to the test bin. The final path of the grain was a vertical section of a 9 m long spout. The velocity of grain entering the spreader from the spout was at least 10 m/s.

In some bin filling operations on the farm the grain is transferred to the top of the grain bin by a screw conveyor. Therefore, the velocity of grain entering the bin is relatively low. This paper reports tests with spreaders at grain velocities similar to those in farm applications.

The objectives of this study were: (a) to evaluate the effectiveness of the 4-trough grain spreader in producing a uniform distribution of fine material within the grain mass under an operating condition that the grain was choke-fed through an orifice to the spreader and (b) to compare the bulk properties of grain transferred to the bin by the 4-trough grain spreader we developed with that of grain transferred by the commercially available self-propelled rotational type grain spreaders.

MATERIALS AND EQUIPMENT

Grain and Grain Bin

Wheat, yellow corn, and grain sorghum were used in these experiments. Two test lots for each kind of grain were used in the tests and each lot was considered a replication. Wheat and grain sorghum were cleaned once with a 2.0 mm round-hole screen before tests and corn was cleaned with a 3.6 mm round-hole screen before each test. Since the breakage caused by handling is higher for corn than for wheat and sorghum, cleaning of corn before each test would reduce the variation in fine material content between tests.

The test bin was 6.4 m in diameter with 5.5 m sidewalls and a 7.4 m peak height. The bin was equipped with a perforated (2.4 mm diameter holes) floor with 13% open area. An 11.3 kW variable-speed fan was used to supply ambient air to the bin subfloor plenum. A mechanical unloading system with a bin sweep auger was used to remove grain from the bin after each test.

Grain Spreaders

The three types of self-propelled rotational grain spreaders used were: (a) a 4-trough spreader which was constructed at the U.S. Grain Marketing Research Laboratory, (b) a commercial 2-trough spreader, and (c) a commercial 1-trough spreader. A vertical spout with no spreader was the control.

Descriptions of the 4-trough spreader (Figs. 1 and 2) and the 2-trough spreader (Fig. 3) were given in the previous paper (Chang et al., 1981).

The 1-trough spreader (Fig. 4) consisted of a mounting frame, hopper, and a discharge trough. The hopper was attached to a shaft suspended in the center of the mounting frame. The trough, 120 cm long and 25 cm wide, was attached to the outlet of the hopper with an incline angle of 32 degrees from the horizontal. Inside

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The authors are: C. S. CHANG, H. H. CONVERSE, and C. R. MARTIN, Agricultural Engineers, U.S. Grain Marketing Research Laboratory, USDA-ARS, Manhattan, KS.

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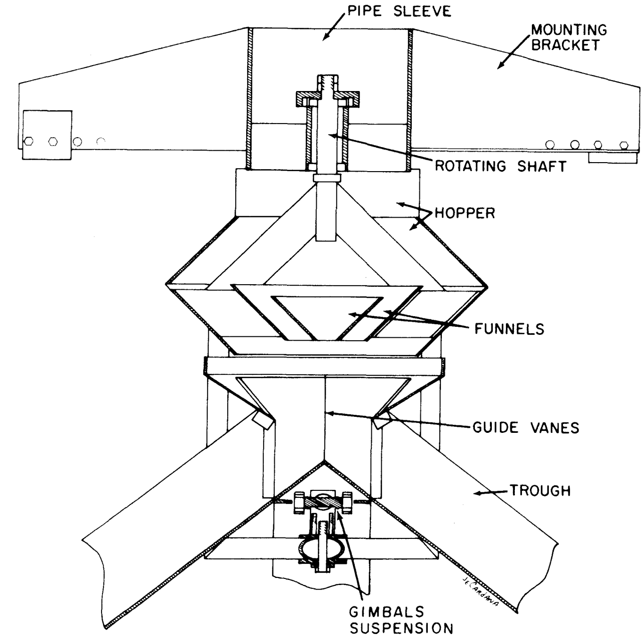

Fig. 1—Schematic of the 4-trough grain spreader designed and built at the U.S. Grain Marketing Research Laboratory.

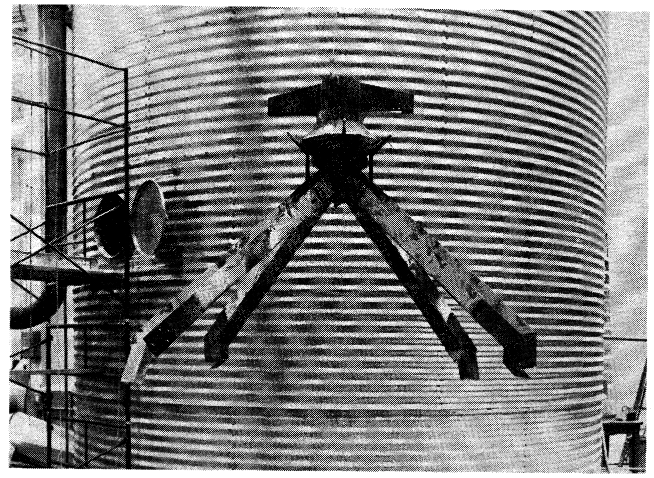

Fig. 2—The 4-trough grain spreader.

the hopper, 4 blades were attached to the sidewalls for distributing grain and rotating the spreader. Three deflectors, attached to the bottom of the trough, spread the grain stream in the bin and rotated the spreader. The position of deflectors and the length of trough were adjustable to control spread of the grain. The capacity of the spreader was 105 m^3/h (3000 bu/h).

Optical Opacity Monitors

Three optical opacity monitors (Eckhoff and Fuhre, 1975; Lee et al., 1980), installed 20 cm from the bin wall at 2, 3.5, and 5 m from the floor, were used to measure the dustiness of air in the bin during the filling operations. Each monitor consisted of a light emitting diode (LED) and a phototransistor (PT) mounted 1 m apart on a steel frame. The LED emitted a constant intensity of infrared radiation to the PT. The intensity of radiation received by the PT was proportional to the dustiness of air in the light path.

Each optical opacity monitor was calibrated so that the output of the device was 3 V at 100% transparency (clean air) and 3.6 V at 50% transparency. Data from each monitor were recorded every 10 s during the first 10 min of each test and every 30 s thereafter.

PROCEDURE

Each test lot (1200 bu) weighed 32.8 t for wheat and 30.5 t for corn and sorghum and filled the test bin to an average depth of 1.2 m. Grain was transferred from the holding bin to the test bin through a grain elevator and a spouting system (Fig. 5). The spouting system consisted of a 23-cm square inclined spout, a 6.4-m long vertical section of a 30-cm round spout, and a 1.5-m long flow control section that ended at the peak of the bin roof or above the spreaders. The flow control section consisted of an iris valve, reducer, a 1.2-m section of 20-cm round spout, and an orifice installed at the end of the spout. The size of the orifice was preselected so that the flow

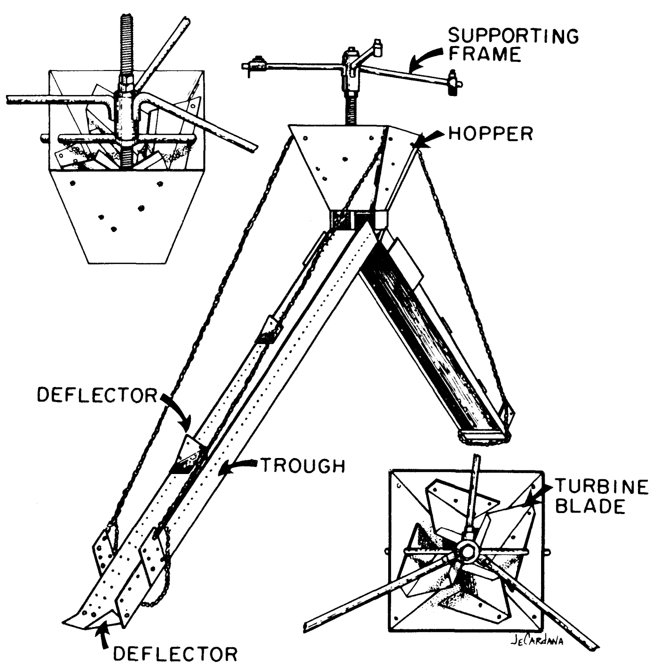

Fig. 3—Schematic of the 2-trough grain spreader manufactured by B. W. Manufacturing Co., Inc., Columbus, NB.

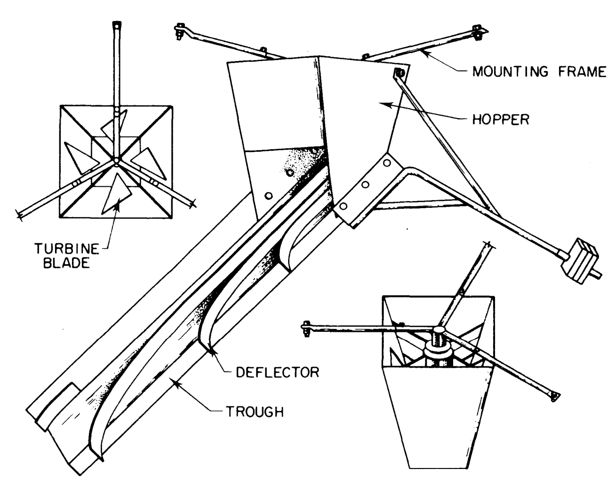

Fig. 4—Schematic of the 1-trough grain spreader manufactured by Winfield Agri-Builder, Winfield, IA.

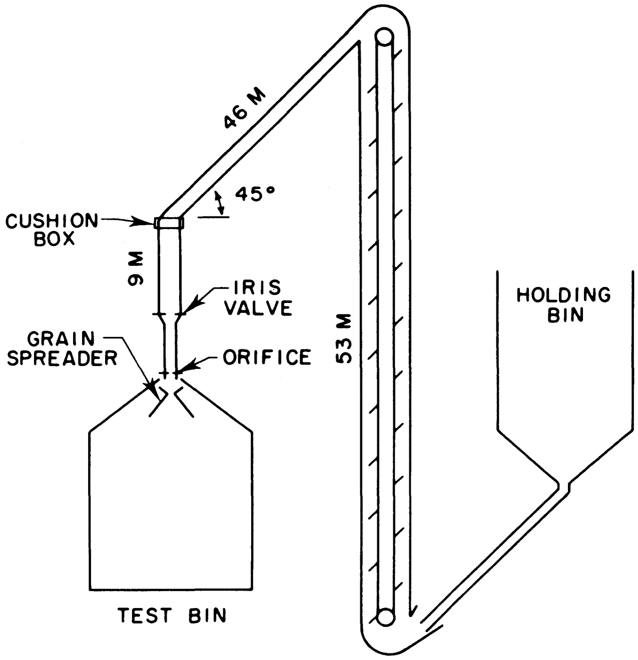

Fig. 5—Grain handling system for grain spreader tests.

rate of grain through the orifice was about 26 t/h (1000 bu/h). The orifices used were 14 cm in diameter for corn and 13 cm in diameter for wheat and sorghum.

The iris valve was closed before each test. When the incoming grain filled up the vertical section of the spout, the iris valve was suddenly opened. Due to the flow restriction created by the orifice, a choke flow of grain through the orifice was established. Grain flow from the orifice to the spreader or directly into the bin was mass flow (similar in appearance to liquid laminar flow). The velocity of grain through the orifice was about 0.6 to 0.7 m/s.

An automatic spout sampler (Carter-Day Mechanical Sampler, CHCI No. 132) located at about 3 m below the elevator discharge point, sampled the grain steam every 2 min. Consecutive groups of 4 samples were combined for analyses of bulk density (test weight), moisture content, and fine material content. Bulk density and moisture content were determined by a grain analysis computer (Model GAC II, Dickey-john Corporation, Auburn, IL). Fine material contents were determined with a 1.6-mm × 9.5-mm oblong-hole sieve for wheat, with a 4.8-mm round-hole sieve for corn, and with a 2.0-mm inscribed circle triangular-hole sieve for sorghum. Particles which passed through the sieve were considered fine material.

After grain was placed in the bin, a standard compartmentalized grain probe was used to obtain grain samples along the diameter of the bin at 30-cm intervals, starting at a point 15 cm from the bin wall. The grain probe was 3 m long, with compartments at 14-cm intervals. Samples from each two adjacent compartments in the probe were combined and screened with appropriate sieves to determine the fine material content. The percentages of fine material content in each sample established the distribution of fine material in the bin.

Wherever grain was sampled, the depth of grain was measured to determine the shape of the grain pile and the volume of grain in the bin. The average bulk density of the grain in the bin was calculated from those data and the weight of the grain lot.

A variable-speed fan supplied air to the grain through the subfloor plenum, and the average airflow resistance of the grain was determined. The airlow rate was measured with a 30-cm diamtere ASME long-radius flow nozzle attached to the fan inlet by a 71-cm diameter duct. Readings were taken at airflow increments of 0.6 $m^3/(min \cdot m^2)$. The static pressure in the plenum was measured at seven pressure taps; one was located at the center of the bin and six were located around the bin circumference. The average static pressure in the plenum was used for analysis. The static pressure in the bin was measured by a pressrure tap in the top of the bin. Differential pressures between the plenum and the air space in the bin were used to calculate the airflow resistance of grain at various airflow rates.

The relationship between airflow rate and the airflow resistance of corn can be expressed by a general equation [1] with common coefficients B and C and a coefficient, A, which varies with the bulk density and fine material content of corn in the bin (Chang et al., 1981):

$$Q = \mathrm{Exp}\,[A + B \cdot \ln P + C\,(\ln P)^2] \quad [1]$$

where
Q = airflow rate, $m^3/(min \cdot m^2)$
P = airflow resistance, Pa/m

Equation [1] was developed based on the data of airflow resistance of corn at various densities and fine material contents (Bern and Charity, 1975; Haque et al., 1978; Shedd, 1953). It was assumed that the same functional relationship can be applied to wheat and grain sorghum.

In equation [1], common coefficients B and C were calculated for wheat, corn, and sorghum by regression analysis using data from Shedd (1953). The coefficient A for grain in the test bin was determined by trial and error so that the total airflow rate calculated from equation [1] at a specific static pressure was equal to the airflow rate delivered by the fan. The total airflow rate was obtained by adding the airflows which passed through each concentric annular grain column in the bin represented by the depth measurements. For each bin filling test, values of A were determined at each increment of airflow. The mean value was used for that particular test. Equation [1] with the values of B and C from each kind of grain and the values of A from each bin filling test was used to determine the effect of filling method on airflow resistance.

Power required to deliver air through grain can be expressed by (Henderson and Perry, 1976):

$$E = Q \cdot P \quad [2]$$

where
E = power, W
Q = airflow rate, m^3/s
P = total pressure, Pa

Equation [2] may be written as:

$$e = q \cdot p \cdot d/60 \quad [3]$$

where
e = power, W/m^2 of bin floor
q = airflow rate, $m^3/(min \cdot m^2)$
p = airflow resistance of grain, Pa/m
d = grain depth, m

TABLE 1. GRAIN CHARACTERISTICS BEFORE TESTS

Grain	Spreader	Fine material content, %	Moisture content, %	Bulk density, kg/m³
	4-trough	1.74	12.5	812
	2-trough	1.90	12.6	819
Wheat	1-trough	2.17	12.5	826
	none (spout)	2.19	12.7	824
	Average	2.00	12.6	820
	4-trough	2.69	12.2	800
	2-trough	3.11	12.7	798
Corn	1-trough	3.49	11.9	789
	none (spout)	3.39	12.1	788
	Average	3.17	12.2	794
	4-trough	3.73	14.1	770
	2-trough	3.76	14.0	771
Sorghum	1-trough	3.97	13.7	766
	none (spout)	4.01	13.7	766
	Average	3.87	13.9	768

Equation [3] was used to calculate the power required to move air through the grain placed in the bin by various filling methods.

RESULTS AND DISCUSSION

Grain characteristics before tests are given in Table 1. The average moisture contents were 12.6, 12.2, and 13.9%, the average bulk densities (test weights) were 820, 794, and 768 kg/m³, and the average fine material contents were 2.00, 3.17, and 3.87% for wheat, corn, and sorghum, respectively.

Distribution of Fine Material

The distribution of fine material in grain transferred to the bin with and without a spreader are given in Table 2 and Figs. 6, 7, and 8. Fine material contents were obtained from samples taken by the grain probe. The volumes of grain in the bin represented by each sample were considered when means for fine material were calculated. In general, more fine material was distributed around the bin center. As reflected by the coefficient of variability, the distribution of fine material contents for all three kinds of grain transferred by the 4-trough spreader, 2-trough spreader, or the spout only were more uniform than that of grain transferred by the 1-trough spreader.

When the 1-trough spreader was used, grain kernels leaving the first deflector in the trough tended to spread away from the bin center; however, fine material fell vertically and settled toward the bin center. This may have been the reason why the fine material content of grain in the center region of the bin was higher for grain transferred with the 1-trough spreader than for grain transferred with the 4-trough spreader or the 2-trough spreader.

The coefficient of variability averaged across various grains for each filling method indicated that the 4-trough spreader, the 2-trough spreader, and the spout provided about the same level of uniformity of fine material distribution in the grain mass. These results indicated that when a choke flow of grain is established by an orifice, there is no advantage of using a spreader for the purpose of improving the uniformity of fine material distribution in the grain mass.

A separate experiment was conducted with corn to

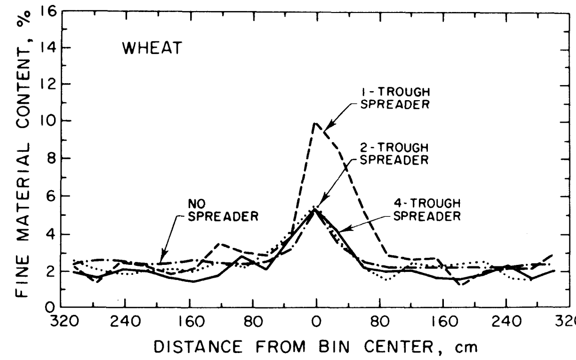

Fig. 6—Radial distributions of fine material in wheat transferred to the bin by different methods.

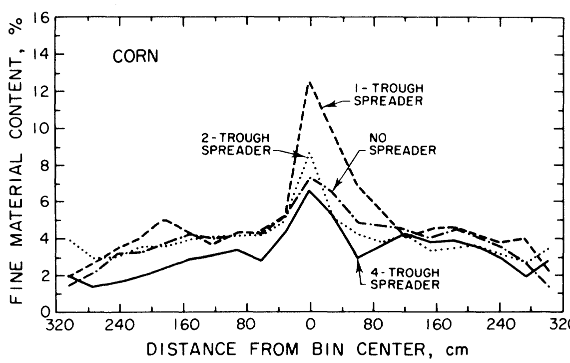

Fig. 8—Radial distributions of fine material in sorghum transferred to the bin by different methods.

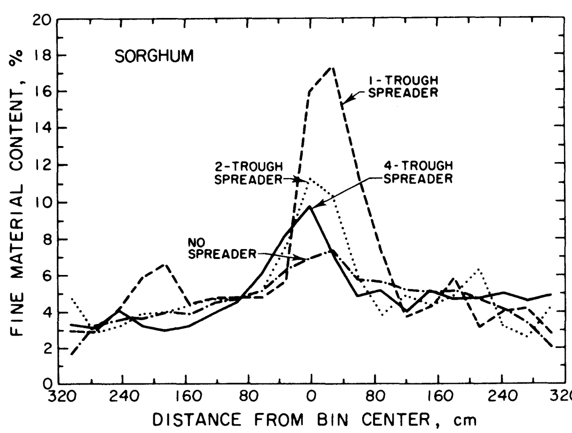

Fig. 7—Radial distributions of fine material in corn transferred to the bin by different methods.

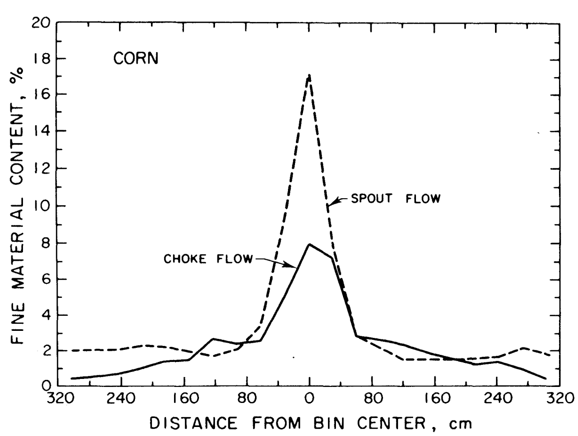

Fig. 9—Radial distribution of fine material in corn transferred to the bin by choke flow and spout flow.

TABLE 2. FINE MATERIAL DISTRIBUTION AND TRANSPARENCY OF AIR IN BIN

Grain	Spreader	Fine material content		Increase in fine material content % point	Coefficient of variability, %	Transparency of air near bin wall, %
		Range, %	Mean, %			
	4-trough	1.4- 5.4	1.95	0.21[a]	42[a]	88[a]
Wheat	2-trough	1.4- 5.7	2.20	0.30[a]	46[a]	89[a]
	1-trough	1.2-10.0	2.43	0.26[a]	66[b]	91[a]
	None (spout)	2.2- 5.3	2.46	0.27[a]	33[c]	96[b]
	4-trough	1.3- 6.6	2.70	0.01[a]	44[ab]	79[a]
Corn	2-trough	2.7- 8.7	3.55	0.45[b]	37[b]	78[a]
	1-trough	1.9-12.6	3.69	0.20[a]	54[c]	91[b]
	None (spout)	1.2- 7.4	3.55	0.16[a]	47[ac]	94[b]
	4-trough	2.6- 9.8	4.21	0.48[a]	38[a]	86[a]
Sorghum	2-trough	2.5-11.4	4.30	0.55[b]	56[b]	87[a]
	1-trough	2.8-17.6	4.40	0.43[bc]	68[c]	93[b]
	None (spout)	1.6- 7.4	4.18	0.18[c]	38[a]	97[b]

Data shown are an average of two replications
[a,b,c]Different superscripts in same column and same kind of grain indicate significant difference at 5% level.

determine the difference in fine material distribution between grain transferred to the bin with a conventional spout flow and a choke flow through an orifice. Results (Fig. 9) showed that the concentration of fine material around the bin center was reduced and the distribution of fine material was improved by the choke flow method. A possible explanation for this improvement in fine material distribution is as follows:

When grain was choke-fed through an orifice, the grain stream looked like a solid grain column: no major separation of kernels and fine material occurred during the fall. After the grain reached the center of the grain pile, both grain kernels and fine material flowed toward the bin wall together. In the conventional spout flow, the velocity of grain leaving the spout was relatively high, and the flow pattern was similar to that of water from a full cone spray nozzle. Grain kernels separated from the fine material during the fall and spread between the bin center and bin wall, while most fine material fell vertically into the bin center. Furthermore, when grain flowed from bin center toward the bin wall, a seiving action took place due to the impact of grain falling on the surface of the grain pile. This seiving action allowed most whole kernels to flow toward the bin wall and left most of the fine material around the bin center.

The distribution of fine material in the grain mass was more uniform in the vertical direction than in the horizontal direction for all filling methods. Maximum differences in fine material content between layers of grain were 1, 2.3, 1.9, and 1.5 percentage points for grain filled with the 4-trough spreader, 2-trough spreader, 1-trough spreader, and the spout, respectively.

It should be noted that the distribution of fine material in grain obtained in these experiments may be different from that obtained from tests conducted in other sizes of bin.

Grain Damage

The increase in fine material content (Table 2) was the difference in fine material content before and after a given test. The increase was mainly caused by the breakage of grain during transferring. After each test, the fine material content increased 0.21 to 0.30% point for wheat, 0.01 to 0.45% point for corn, and 0.18 to 0.55% point for sorghum. As reported previously (Chang et al., 1981), the fine material content increased 1 to 1.6% point for corn transferred to the bin under non-choke flow condition. Thus choke flow caused less damage to the corn than non-choke flow.

Among the four filling methods, the differences in the increase in fine material content for wheat were not significant. However, the increase in fine material content for corn transferred by the 2-trough spreader was significantly higher than that for corn transferred by the other three methods. The increase in fine material content for sorghum transferred by the 2-trough spreader or 4-trough spreader was significantly higher than that for sorghum transferred by the spout.

Among the four filling methods, the 2-trough spreader caused the most grain damage, probably due to the fact that this spreader had more sharp edges in turbine blades than did the 4-trough spreader or the 1-trough spreader. Consequently, grain had a high chance of contacting blade edges and breaking.

Dust Concentration in the Air Above the Grain

The transparency data (Table 2) show that the dust concentration of air in the bin was higher when spreaders were used due to the spreading action. However, it is far below the minimum explosible concentration (Jacobson et al., 1961; Martin et al., 1980). Among the three types of spreaders used, the 1-trough spreader emitted less dust than did the 2-trough or the 4-trough spreaders.

Bulk Density

The bulk densities of grain in the bin ranged from 840 to 917 kg/m³ for wheat, from 778 to 853 kg/m³ for corn, and from 780 to 876 kg/m³ for sorghum (Table 3). The bulk densities of all three kinds of grain transferred to the bin with grain spreaders were significantly higher than those of grain transferred without a spreader. Bulk densities increased 5.1 to 9.2% for wheat, 5.8 to 9.6% for corn, and 11.4 to 12.3% for sorghum when spreaders were used.

In this experiment, each test lot of grain filled the test bin to an average depth of 1.2 m which was about 22% of the bin height. When a bin is fully filled, the bulk density of grain in the bottom portion of the bin may be higher than that of grain in the top portion due to the difference in dropping height from the spreader, and the packing effect of the added grain. Therefore, the bulk density of grain obtained from this experiment may be lower than the average bulk density of grain obtained when a bin is fully filled.

TABLE 3. BULK DENSITY AND AIRFLOW RESISTANCE OF GRAIN PLACED IN THE BIN BY VARIOUS FILLING METHODS

Grain	Spreader	Bulk density, kg/m^3	Increase* in bulk density, %	Airflow† resistance, Pa/m	Power† requirement for moving air through grain $W/(m^2 \cdot m)$	Increase in* airflow resistance or power requirement, %
	4-trough	917^a	9.2	508^a	38.9^a	61
Wheat	2-trough	883^b	5.1	489^b	37.5^b	55
	1-trough	902^{ab}	7.4	527^c	40.4^c	67
	None (spout)	840^c		315^d	24.2^d	
	4-trough	853^a	9.6	211^a	16.2^a	111
Corn	2-trough	823^b	5.8	217^{ab}	16.6^{ab}	117
	1-trough	843^a	8.4	226^b	17.3^b	126
	None (spout)	778^c		100^c	7.7^c	
	4-trough	870^a	11.5	498^a	38.2^a	126
Sorghum	2-trough	876^a	12.3	522^a	40.0^a	137
	1-trough	869^a	11.4	546^a	41.9^a	148
	None (spout)	780^b		220^b	16.9^b	

Data shown are an average of two replications
a,b,c,d Different superscripts in same column and same kind of grain indicate significant difference at 5% level.
* Values from spout were used as the basis.
† At an airflow rate of 4.6 $m^3/(min \cdot m^2)$

Airflow Resistance of Grain

The relationship between airflow rate and airflow resistance of grain placed in the bin with different bin filling methods are shown in Figs. 10, 11, and 12. All curves are expressed by equation [1] with coefficients given in Table 4. For the same kind of grain, the coefficient A varied with the filling methods and can be considered a pack factor. Airflow resistances of all three kinds of grain placed in the bin with spreaders were significantly higher than those of grain placed in the bin without a spreader. These results are similar to those reported by Stephens and Foster (1976; 1978). The higher airflow resistance was mainly caused by the higher bulk density of the grain. Airflow resistance of grain in the bin transferred without a spreader were very close to the values obtained by Shedd (1953).

TABLE 4. COEFFICIENTS IN EQUATION (1)

Grain	Spreader	Coefficients A	B	C
Wheat	4-trough	- 4.369	1.084	- 0.0221
	2-trough	- 4.338		
	1-trough	- 4.398		
	None (spout)	- 3.978		
	Shedd's curve*	- 3.961		
Corn	4-trough	- 2.953	1.014	- 0.0331
	2-trough	- 2.970		
	1-trough	- 3.005		
	None (spout)	- 2.437		
	Shedd's curve*	- 2.432		
Sorghum	4-trough	- 4.939	1.322	- 0.0451
	2-trough	- 4.975		
	1-trough	- 5.007		
	None (spout)	- 4.303		
	Shedd's curve*	- 4.404		

* (Shedd, 1953)

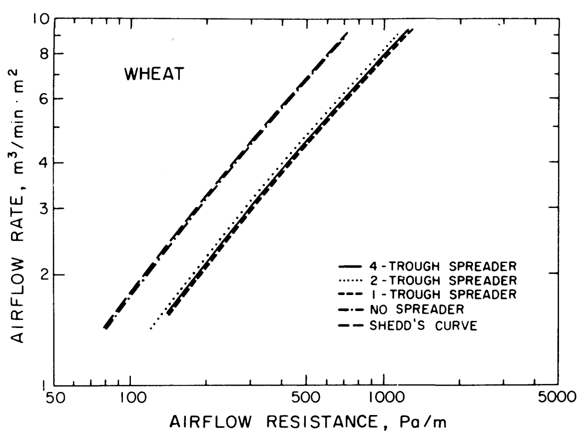

Fig. 10—Relationships of airflow rate and airflow resistance of wheat transferred to the bin by different methods.

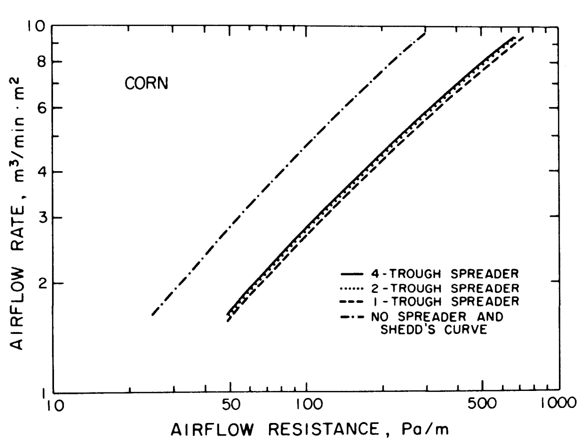

Fig. 11—Relationships of airflow rate and airflow resistance of corn transferred to the bin by different methods.

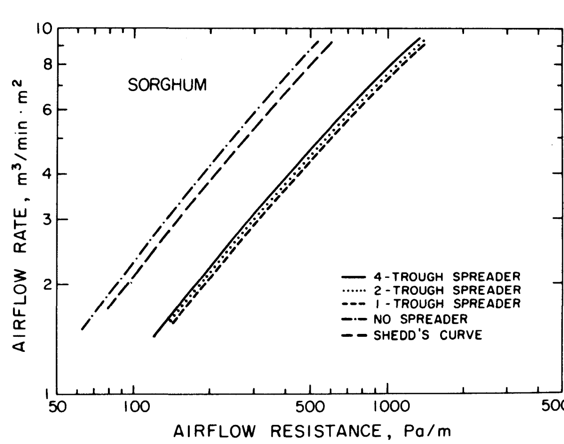

Fig. 12—Relationships of airflow rate and airflow resistance of sorghum transferred to the bin by different methods.

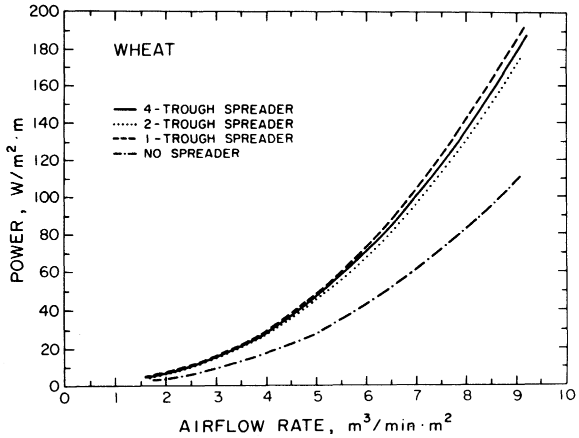

Fig. 13—Relationships of power requirement and the rate of airflow through wheat transferred to the bin by different methods.

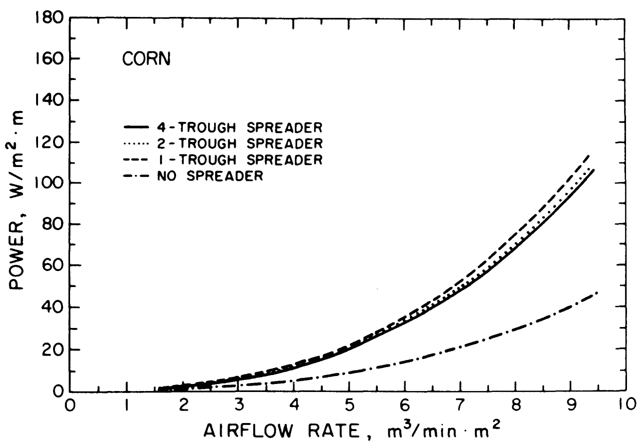

Fig. 14—Relationships of power requirement and the rate of airflow through corn transferred to the bin by different methods.

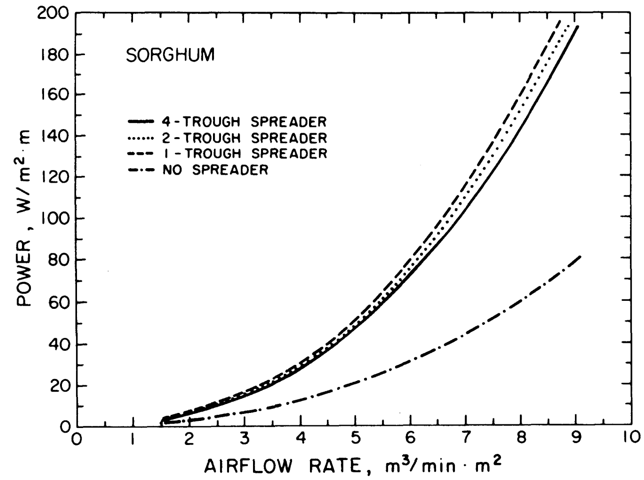

Fig. 15—Relationships of power requirement and the rate of airflow through sorghum transferred to the bin by different methods.

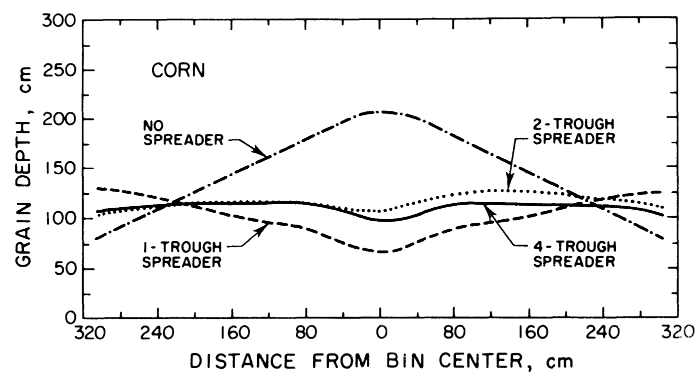

Fig. 16—Radial distributions of corn transferred to the bin by different methods.

At an airflow rate of 4.6 $m^3/(min \cdot m^2)$, the airflow resistances of wheat transferred to the bin with spreaders ranged from 489 to 527 Pa/m, which were 55 to 67% higher than those of wheat transferred without a spreader (Table 3). Air flow resistances of corn and sorghum placed in the bin with spreaders were more than double of those obtained when no spreader was used. At the same airflow rate, the airflow resistances of wheat and sorghum were more than twice as much as corn.

Power Requirements

Power required to move air through grain is proportional to the resistance of grain to the airflow. The relationships between net power requirement and the rate of airflow through 1-m depth of grain are shown in Figs. 13, 14, and 15. At the same airflow rate, the grain transferred with spreaders required significantly larger power than grain transferred with a spout. At an airflow rate of 4.6 $m^3/(min \cdot m^2)$ power requirements ranged from 24.2 to 40.4 $W/(m^2 \cdot m)$ (W per m^2 of floor area per m depth of grain) for wheat, from 7.7 to 17.3 $W/(m^2 \cdot m)$ for corn, and from 16.9 to 41.9 $W/(m^2 \cdot m)$ for sorghum. To move air at this rate through a 6.4-m diameter bin filled with 6-m depth of grain, the power requirements were 4.6, 1.5, and 3.3 kW, respectively, for wheat, corn, and sorghum transferred with a spout, and 7.5, 3.2, and 7.7 kW respectively, for wheat, corn, and sorghum transferred with spreaders. The increases in power requirements were 63, 113, and 133% for wheat, corn, and sorghum, respectively, due to the use of spreaders resulting in higher bulk grain density.

Surface Contour of the Grain Pile

In general, when the 4-trough spreader or the 2-trough spreader was used, the surface contour of the grain pile was reasonably level (Fig. 16). When the 1-trough spreader was used, grain near the bin wall was deeper than at the bin center. When grain was placed in the bin with a spout, the grain pile was conical and the surface of the grain pile at the bin center was about 1.5 m higher than that near the bin wall.

In these experiments the trough of the 1-trough spreader was adjusted to the shortest position; however it still spread an excessive amount of grain toward the bin wall. Thus, the 1-trough spreader may be more suitable for bins with a diameter larger than 6.4 m. The manufacturer of the 1-trough spreader recommends that it be used for bin sizes ranging from 4.6 to 11 m in diameter.

The 2-trough spreader, with its troughs set at the lowest position in these experiments, provided a reasonable level fill. By adjusting the angle of the trough, the 2-trough spreader may be suitable for bins of 6.4 m in diameter or larger. The manufacturer recommends that the 2-trough spreader be used for bin size up to 12 m in diameter.

By adjusting deflectors at the lower end of each trough, the 4-trough spreader may be used for bin sizes ranging from 5.5 to 9 m in diameter.

It should be noted that the surface contour of the grain pile obtained in these experiments may be different from that obtained from tests conducted in other sizes of bin.

The rotating speeds of the 4-trough spreader, 2-trough spreader, and the 1-trough spreader were 2, 5, and 8 r/min, respectively. The speed of the 2-trough spreader and the 1-trough spreader was not adjustable; however, the speed of the 4-trough spreader can be adjusted by adjusting the angle of the deflectors at the lower end of each trough. A slight change in rotating speed (2 to 3 r/min) should not affect the bulk properties of grain in the bin.

SUMMARY AND CONCLUSIONS

1. A self-propelled rotational 4-trough grain spreader constructed at the USGMRL was used to load a 6.4-m diameter bin with grain. Its performance was compared with that of two commercially available rotational type grain spreaders. The grain for filling was coke-fed to an orifice instralled at the end of a spout and then to the spreader. A vertical spout with no spreader was the control method for filling the bin with grain.
2. Use of the 4-trough spreader or the 2-trough spreader to fill a bin with grain provided a reasonably level surface without hand labor.
3. When the grain for loading was choke-fed through an orifice, there was no advantage of using a spreader for the purpose of improving the uniformity of fine material distribution in the grain mass.
4. Damage to the grain during transferring was lower for choke-flow than for nonchoke flow.
5. The use of grain spreaders increased the bulk density and airflow resistance of grain and also increased the power requirement for moving air through the grain over that obtained when no spreader was used.
6. The use of grain spreaders increased the dustiness of air in the bin.

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